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(54) PROCESS AND APPARATUS FOR SHAPE CASTING OF PARTICLE STABILIZED METAL FOAM

VERFAHREN UND VORRICHTUNG ZUM FORMGIESSEN EINES MITTELS TEILCHEN  
STABILISIERTEN METALLSCHAUMES

PROCEDE ET DISPOSITIF DE MOULAGE PAR COULEE D'UNE MOUSSE METALLIQUE  
STABILISEE PAR DES PARTICULES

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**Description**

This invention relates to a process and apparatus for shape casting particle stabilized metal foam, particularly particle stabilized aluminum foam, according to the preamble of claim 1.

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**Background Art**

Lightweight metal foams have high strength-to-weight ratios and are extremely useful as load-bearing materials and as thermal insulators. Metal foams are characterized by high impact energy absorption capacity, low thermal conductivity, good electrical conductivity and high absorptive acoustic properties.

A particle stabilized metal foam of exceptional stability is described in Jin et al U.S. Patent 4,973,358, issued November 27, 1990. According to that patent, a composite of a metal matrix and finely divided solid stabilizer particles is heated above the liquidus temperature of the metal matrix. Gas is then introduced into the molten metal composite below the surface of the composite to form bubbles therein. These bubbles float to the top surface of the composite to produce on the surface a closed cell foam. The foam which forms on the surface of the molten metal composite is a highly stable liquid foam, i.e. the foam cells do not collapse under their own weight. This stable liquid foam is then cooled below the liquidus temperature of the melt to form a metal foam product having a plurality of closed cells and the stabilizer particles dispersed within the metal matrix.

A method for shaping metal foam is described in Nieblyski et al, U.S. Patent 3,873,392, issued March 25, 1975, in which solid metal foam is compressed such that cell walls are crushed. Although heat may be used, it is preferred that the temperature does not exceed about 38°C below the melting point of the base metal.

Another method for shaping a metal foam body is described in Erb, U.S. Patent 3,595,059, issued July 27, 1971. In this method, the forming device is reciprocated causing localized heating and crushing of the walls of the foam structure.

Shape casting of molten metals, such as aluminum, can be carried out in a wide variety of closed moulds. One such technique is squeeze casting, also known as liquid-metal forging, in which molten metal solidifies under pressure within closed dies positioned between the plates of a hydraulic press. The applied pressure and the instant contact of the molten metal with the die surface produces a rapid heat transfer condition that yields a pore-free fine-grain casting with mechanical properties approaching those of a wrought product. Semi-solid metal working is also used, which incorporates elements of both casting and forging. This may be referred to as rheocasting, thixocasting or stir casting. In this procedure a thixotropic material is formed which can be moved and handled.

It is the object of the present invention to provide a shape casting technique for particle stabilized metal foam which takes advantage of the unique characteristics of the particle stabilized metal foam.

**Disclosure of the Invention**

In the present invention, a composite of a metal matrix, e.g. aluminum alloy, and finely divided solid stabilizer particles is heated above the solidus temperature of the metal matrix. Gas is then introduced into the molten metal composite below the surface of the composite to form bubbles therein and these bubbles float to the surface of the composite to produce on the surface a stabilized liquid metal foam.

In accordance with the novel feature of the present invention, it has been found that the stabilized liquid metal foam has considerable structural integrity and can be shape cast by pressing the stabilized liquid foam, into a mould. This is done using a pressure sufficient only to cause the liquid foam to assume the shape of the mould without substantial compressing and/or collapsing of the cells of the foam. Thereafter, the foam is cooled and solidified to obtain a shaped article.

The stabilized liquid foam is preferably continuously drawn off from the surface of the molten metal composite and thereafter cast into the shaped, solidified metal foam article. The shape casting is done while the foam is in the liquid form either immediately after foam generation or by reheating a previously cast slab of liquid foam to temperatures above the solidus temperature.

The shape casting can be done by a variety of techniques, such as squeeze casting, etc. Since the foam is in the liquid or liquid+solid state, the pressure required to deform the foam is low. Cells do not collapse under pressure since within the mould the cells are under a state of hydrostatic stress. Thus, density of the formed part is essentially unchanged from that of the starting foam material. The formed article exhibits a continuous skin due to the metal flow during the shaping operation.

The term "shape casting" as used in the present invention means that the liquid foam is pressed into a mould sufficient only to cause the liquid foam to assume the shape of the mould without compressing and/or collapsing the cells of the foam. Although, the pressing into the mould must be done carefully to avoid compressing and/or collapsing the cells, it surprisingly can be carried out at high rates without any problems. It is also possible to subject the foam to "shape forming" in which the foam within the mould is subjected to further deformation. This shape forming can be done

when the metal foam is in the liquid or liquid/solid state and it can be done with or without densification of the foam. For instance, foam outside the mould proper, e.g. a flange, may be compressed resulting in densification of the foam in that area. It is also possible to press a shape forming tool into the foam in a mould to further modify the shape of the article being cast without densifying it. An important advantage of the processes of the present invention is that parts can be made to net or near net shapes, thereby avoiding machining.

The success of the forming method is highly dependent upon the nature and amount of the finely divided solid refractory stabilizer particles. A variety of such refractory materials may be used which are particulate and which are capable of being incorporated in and distributed through the metal matrix and which at least substantially maintain their integrity as incorporated rather than losing their form or identity by dissolution in or chemical combination with the metal.

Examples of suitable solid stabilizer materials include alumina, titanium diboride, zirconia, silicon carbide, silicon nitride, magnesium oxide, etc. The volume fraction of particles in the foam is typically less than 25% and is preferably in the range of about 5 to 15%. The particle sizes can range quite widely, e.g. from about 0.1 to 100  $\mu\text{m}$ , but generally particle sizes will be in the range of about 0.5 to 25  $\mu\text{m}$  with a particle size range of about 1 to 20  $\mu\text{m}$  being preferred.

The particles are preferably substantially equiaxial. Thus, they preferably have an aspect ratio (ratio of maximum length to maximum cross-sectional dimension) of no more than 2:1. There is also a relationship between particle sizes and the volume fraction that can be used, with the preferred volume fraction increasing with increasing particle sizes. If the particle sizes are too small, mixing becomes very difficult, while if the particles are too large, particle settling becomes a significant problem. If the volume fraction of particles is too low, the foam stability is then too weak and if the particle volume fraction is too high, the viscosity becomes too high.

The metal matrix may consist of any metal which is capable of being foamed. Examples of these include aluminum, steel, zinc, lead, nickel, magnesium, copper and alloys thereof.

The foam-forming gas may be selected from the group consisting of air, carbon dioxide, oxygen, water, inert gases, etc. Because of its ready availability, air is usually preferred. The gas can be injected into the molten metal composite by a variety of means which provide sufficient gas discharge pressure, flow and distribution to cause the formation of a foam on the surface of the molten composite. Preferably, a strong shearing action is imparted to a stream of gas entering the molten composite, thereby breaking up the injected gas stream into a series of bubbles. This can be done in a number of ways, including injecting the gas through a rotating impeller, or through a vibrating or reciprocating nozzle. It is also possible to inject the gas within an ultrasonic horn submerged in the molten composite, with the vibrating action of the ultrasonic horn breaking up the injected gas stream into a series of bubbles. The cell size of the foam can be controlled by adjusting the gas flow rate, as well as the impeller design and rotational speed where used or the amplitude and frequency of oscillation or vibration where an oscillating or vibrating system is used.

In forming the foam according to this invention, the majority of the stabilizer particles adhere to the gas-liquid interface of the foam. This occurs because the total surface energy of this state is lower than the surface energy of the separate liquid-gas and liquid-solid state. The presence of the particles on the bubbles tends to stabilize the froth formed on the liquid surface. It is believed that this may happen because the drainage of the liquid metal between the bubbles in the froth is restricted by the layer of solids at the liquid-gas interfaces. The result is a liquid metal foam which is not only stable, but also one having uniform pore or cell sizes throughout the foam body since the bubbles tend not to collapse or coalesce.

The pores or cells of the foam may be as large as 50 mm, provided they are uniform in size. However, small uniform cell sizes averaging less than 5 mm are preferred. The small cell sizes have the advantage of easily moving or deforming during shaping to fill the mould. With larger cells, on the other hand, shearing or tearing of the cell walls may occur when complex shapes are made.

In a preferred embodiment of the present invention, a layer of stabilized liquid foam is drawn off a foam generating box and this freshly generated foam layer is pressed by a platen down into a preheated mould. The formed article exhibits a continuous outer skin due to metal flow during the shaping operation.

In another preferred embodiment, a previously cast slab of stabilized metal foam is heated to temperatures above the solidus and this reheated slab is again pressed down into a preheated mould by means of a platen to form a shaped article with a continuous outer skin. This provides a more rigid area for attachment of the shaped part to other structures.

In another preferred embodiment of the invention, it is possible to draw the freshly formed stabilized metal foam away from the foam generating box on a conveyor belt, e.g. a steel belt, and an inverted mould is pressed downwardly from above into the foam travelling on the belt. This is capable of forming a shaped article in the same manner as the previously described platen pressing the foam downwardly into a mould.

In other embodiments utilizing a continuous belt, a series of individual moulds may be mounted on a conveyor belt and these individual moulds pick up stabilized foam emerging from a foam generating box, with the foam being pressed into the travelling moulds by means of platens. Alternatively, a continuous profiled slab of foam may be formed while travelling on a conveyor belt by means of profiled rolls engaging the slab.

Brief Description of the Drawings

In the drawings which illustrate the present invention:

- 5      Figure 1 is a sectional view of a metal foam generating box and mould for forming shaped parts;
- Figure 2 is a sectional view of the mould of Figure 1 with the part formed;
- Figure 3 is a sectional view of a mould for moulding precast and reheated foam;
- Figure 4 is a sectional view of the mould of Figure 3 with the part formed;
- Figure 5 is a sectional view of a mould forming a bowl-shaped part in a first stage;
- 10     Figure 6 is a sectional view of the mould of Figure 5 in a second stage;
- Figure 7 is a sectional view showing a system for moulding a part from foam travelling on a conveyor belt;
- Figure 8 is a sectional view of the system of Figure 7 with the part formed;
- Figure 9 is a diagrammatic sectional view of a foam generating box and conveyor belt;
- 15     Figure 10 is a diagrammatic sectional view of a conveyor belt carrying individual moulds;
- Figure 11 is a diagrammatic sectional view of a conveyor system for forming a continuous profiled foam strip;
- Figure 12 is a photomicrograph of typical metal foam used for the invention;
- Figure 13 is a further enlarged photomicrograph showing details of the foam cells;
- Figure 14 is a photograph of a bowl-shaped part with a portion cut away; and
- 20     Figure 15 is a photograph of a slice through a profiled part, and
- Figure 16 (on the sheet with Figures 1 and 2) is a diagrammatic sectional view of a system for forming a curved foam strip.

Best Modes For Carrying Out the Invention

25     As seen in Figure 1, a metal foam generator 10 comprises a vessel 11 having a divider wall 15 extending between side walls to form a foaming chamber 12 and a holding chamber 13. The holding chamber 13 holds a composite of molten metal matrix and finely divided solid stabilizer particles. Fresh composite is added to chamber 13 as needed. An air injecting impeller 14 with air discharge holes in the impeller extends into the foaming chamber 12 and the mixing action of the impeller with the injection of air therethrough creates foam 16 which rises from the surface of the molten metal composite in the foaming chamber 12. A typical foam is made from Al - 9 Si - 0.8 Mg - 15 SiC composite alloy with small average foam cell size of less than about 5 mm.

Because of the strong and resilient nature of the stabilized liquid foam produced from the composite in the foaming chamber, this foam can be simply drawn off from the surface of the foaming chamber 12.

The freshly formed stabilized liquid foam 16 was drawn above a preheated mould 19 mounted on a support 17. A platen 18 moved downwardly, pushing the foam 16 into the mould 19 to form a shaped article as shown in Figure 2 with a densified flange area 21.

Figures 3 and 4 show an alternative embodiment in which a metal foam block 22 was positioned above mould 19. This preform was preheated to above the liquidus temperature of the metal, i.e. 650°C, before being placed over the mould and the mould was also preheated, to about 300°C. The platen 18 was then moved downwardly, compressing the preform 22 into the mould 19 to form a slotted brick shape 23 as shown in Figure 4. A densified flange area 24 was formed at the periphery of the shaped part. The flange is denser, (consisting of flattened cells) and as such provides a more rigid area for attachment of the shaped part to other structures. For example, holes may be drilled in the flange and bolts or screws inserted through to an underlying structure.

A bowl-shaped article may be formed using the mould system of Figures 5 and 6. Stabilized liquid foam 27 was placed in the bottom of a graphite bowl-shaped mould 25 and a refractory platen 26 was used to compress and form the exterior surface. The platen 26 was then replaced by a conical shaped platen 29 also formed of graphite which was pressed into the foam to shape form the interior wall of the bowl-shaped final article 30.

Figures 7 and 8 show an arrangement in which stabilized liquid foam 31 was carried on a steel conveyor belt 32. An inverted cylindrical steel mould 33 was pressed downwardly into the foam 31 as shown in Figure 8 to create a shaped foam article 34.

Figure 9 shows the identical foam generator as described in Figure 1, but in this case the foam 16 which was generated was drawn off onto steel conveyor belt 36 which is carried by drive rolls 37. Typical conditions for producing a metal foam with cells of less than about 3 mm are as follows:

5	Alloy	A356±15% SiC
	Melt Temp.	720°C-630°C
	Casting Speed	12 cm/minute
	Air Flow Rate (nominal)	.3 l/minute
10	Impeller Speed	1050 rpm
	Slab Dimensions (approx.)	5 cm thick x 17 cm wide x 150 cm long

Alternative forms of conveyor belts are shown in Figures 10 and 11, with Figure 10 showing a series of separate moulds 40 mounted in spaced relationship on a conveyor belt 42 travelling on drive rolls 43. As the moulds 40 move past the foam generator 10 they pick up foam as shown and the foam is pressed down into the moulds 40 by means of platen 41 in the same manner as described in Figures 1 and 2.

It is also possible according to the present invention to create a continuous profiled strip of foam and this is described in Figure 11. In this case, a steel belt 42 and drive rolls 43 are again used, but a continuous layer of foam 16 is drawn from the foam generator 10 and this continuous layer 16 of foam is then compressed by means of roll 45 with a profiled shape 46.

It is also possible according to the present invention to create curved strips of foam and this is described in Figure 16. In this case a rotating steel roller 50 is used to pick up the foam 16 starting at a delimiting end stop 51 from the foam generator 10. The foam is pressed down by a rotating shaping roller 53. A shear or similar means 54 is provided to create a second delimiting edge and it is activated when the desired amount of curvature has been cast. The shear may be independent of the rollers as shown in Figure 16 or incorporated as part of the shaping roller itself. The roller 50 may be cylindrical as shown or have non-cylindrical form such as an ellipse or oval. The roller 50 and the shaping roller 53 may also be contoured as in the example of Figure 11 to provide for curved shapes with surfaces that are not flat in form.

The nature of the foam is illustrated by Figures 12 and 13 with Figure 12 being a 4x magnification and Figure 13 being a 100x magnification. Particularly Figure 13 shows the structure of the walls between the cells lined by stabilizing particles. The foam which is used has an average cell size in the range of 2-3 mm.

A metal foam bowl produced by the technique of Figures 5 and 6 is shown in the photograph of Figure 14. This photograph is of a bowl formed of particle stabilized aluminum foam which has been cut to expose the structure. It will be seen that dense layers were formed at the surfaces, but there was no breakdown of the foam structure itself.

The product formed by the system of Figures 1 and 2 is shown in Figure 15. Again, the dense outer surface can be seen and it could also be seen that the interior foam structure remained essentially unchanged.

While preferred embodiments of the present invention have been described in detail for the advantages of the specific details and for purposes of illustration, further modifications, embodiments and variations are contemplated according to the broader aspects of the present invention, all as determined by the scope of the following claims.

### Claims

1. A process for producing shaped articles (23,30,34) of foam metal in which a stabilized liquid foam metal (16) is formed by heating a composite of a metal matrix and finely divided solid stabilizer particles above the solidus temperature of the metal matrix and discharging gas bubbles into the molten metal composite below the surface thereof to thereby form a stabilized liquid foam (16) on the surface of the molten metal composite, characterized by shape casting said stabilized liquid foam metal (16) by pressing the stabilized liquid foam into a mould (19,25,33) with a pressure sufficient only to cause the liquid foam to assume the shape of the mould without substantial compressing and/or collapsing of the cells of the foam and thereafter cooling and solidifying the foam to obtain a shaped article.
2. A process as claimed in claim 1, characterized in that the stabilized liquid foam (16) is a freshly generated foam.
3. A process as claimed in claim 1, characterized in that the stabilized liquid foam (16) is a previously cast stabilized metal foam which has been heated to a temperature above the solidus temperature.
4. A process as claimed in claim 1, characterized in that the mould (19,25,33) is preheated before the stabilized liquid foam (16) is pressed therein.

5. A process as claimed in claim 1, characterized in that the metal is an aluminum alloy.
6. A process as claimed in any one of claims 1 to 5, characterized in that the stabilized liquid foam (16) is pressed into the mould (19) by means of a movable platen (18).
7. A process as claimed in claim 6, characterized in that a first movable platen (26) presses the stabilized liquid foam (16) into the mould (25) and forms smooth exterior surfaces on a shaped foam article (27) and a second platen (29) is pressed into the stabilized liquid foam within the mould (25) to form smooth interior surfaces on a shaped foam article (30).
10. A process as claimed in any one of claims 1 to 5, characterized in that the stabilized liquid foam (31) is carried on a moving belt (32) and a vertically reciprocating inverted mould (33) is pressed downwardly into the stabilized liquid foam (31) on the belt (32) to thereby form a shaped foam article (34).
15. 9. A process as claimed in any one of claim 1 to 5, characterized in that a plurality of mould (40) mounted on a conveyor belt (42) pick up stabilized liquid foam (16) from a foam generator and the foam picked up by each mould is pressed into the mould (40) by means of a reciprocating platen (41).
20. 10. A process as claimed in any one of claims 1 to 5, characterized in that the stabilized liquid foam (16) has cells of uniform size.
25. 11. A process as claimed in claim 10, characterized in that cells of the stabilized liquid foam (16) have uniform average sizes of less than 5 mm.
12. A process as claimed in claim 1, characterized in that the shape casting is squeeze casting.
30. 13. A process as claimed in claim 1, characterized in that the shape casting operation is followed by a shape forming operation.
14. A process as claimed in claim 5, characterized in that the stabilized liquid foam (16) is carried on a moving roller (50) and a second roller (53) is pressed into the stabilized liquid foam (16) on the first roller (50) to thereby form a curved and shaped foam article.

#### Patentansprüche

35. 1. Verfahren zur Herstellung von geformten Gegenständen (23, 30, 34) aus Schaummetall, bei dem ein stabilisiertes, flüssiges Schaummetall (16) ausgebildet wird, indem ein Verbund aus einer Metallmatrix und fein verteilten festen Stabilisierungsteilchen über die Solidustemperatur der Metallmatrix erwärmt wird, und Gasblasen in den geschmolzenen Metallverbund unterhalb dessen Oberfläche abgelassen werden, um dadurch einen stabilisierten flüssigen Schaum (16) an der Oberfläche des geschmolzenen Metallverbundes auszubilden, gekennzeichnet durch Formgießen des stabilisierten flüssigen Schaummetalles (16) durch Pressen des stabilisierten flüssigen Schaumes in eine Form (19, 25, 33) mit einem Druck, der nur ausreicht, um zu bewirken, daß der flüssige Schaum die Gestalt der Form annimmt, ohne daß die Zellen des Schaums wesentlich komprimiert und/oder zusammengedrückt werden, und nachfolgendes Kühlen und Verfestigen des Schaumes, um einen geformten Gegenstand zu erhalten.
40. 2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (16) ein frisch erzeugter Schaum ist.
45. 3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (16) ein vorher gegossener stabilisierter Metallschaum ist, der auf eine Temperatur oberhalb der Solidustemperatur erwärmt wurde.
50. 4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Form (19, 25, 33) vorerhitzt wird, bevor der stabilisierte flüssige Schaum (16) in diese gedrückt wird.
55. 5. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Metall eine Aluminiumlegierung ist.
6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (16) mittels einer beweglichen Platte (18) in die Form (19) gedrückt wird.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß eine erste bewegliche Platte (24) den stabilisierten flüssigen Schaum (16) in die Form (25) drückt und an einem geformten Schaumgegenstand (27) glatte Außenflächen ausbildet, und daß eine zweite Platte (29) in den stabilisierten flüssigen Schaum innerhalb der Form (25) gedrückt wird, um an einem geformten Schaumgegenstand (30) glatte Innenflächen auszubilden.
- 5 8. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (31) auf einem sich bewegenden Gurt (32) getragen wird, und daß eine vertikal hin- und hergehende verkehrte Form (33) nach unten in den stabilisierten flüssigen Schaum (31) auf den Gurt (32) gedrückt wird, um dadurch einen geformten Schaumgegenstand (34) auszubilden.
- 10 9. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß mehrere an einem Fördergurt (42) angebrachte Formen (40) den stabilisierten flüssigen Schaum (16) von einem Schaumerzeuger aufnehmen, und daß der von jeder Form aufgenommene Schaum mittels einer hin- und hergehenden Platte (41) in die Form (40) gedrückt wird.
- 15 10. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (16) Zellen mit gleichmäßiger Größe aufweist.
- 20 11. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die Zellen des stabilisierten flüssigen Schaums (16) eine gleichmäßige durchschnittliche Größe von weniger als 5 mm aufweisen.
12. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Formgießen ein Preßgießen ist.
- 25 13. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß auf den Formgießvorgang ein Vorgang zur Ausbildung einer Form folgt.
14. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß der stabilisierte flüssige Schaum (16) auf einer sich bewegenden Rolle (50) getragen wird, und daß eine zweite Rolle (53) in den stabilisierten flüssigen Schaum (16) auf der ersten Rolle (50) gedrückt wird, um dadurch einen gekrümmten und geformten Schaumgegenstand auszubilden.

#### Revendications

1. Procédé de fabrication d'articles profilés (23, 30, 34) en métal alvéolaire, dans lequel un métal alvéolaire liquide stabilisé (16) est formé par le chauffage, au-dessus de la température solidus de la matrice métallique, d'un composite constitué d'une matrice métallique et de particules finement divisées de stabilisateur à l'état solide et le déchargement de bulles de gaz dans le composite métallique en fusion, au-dessous de sa surface, afin de former de ce fait une mousse liquide stabilisée (16) sur la surface du composite métallique en fusion, caractérisé par une coulée à la forme dudit métal alvéolaire liquide stabilisé (16), par un pressage de la mousse liquide stabilisée dans un moule (19, 25, 33) avec une pression suffisante pour forcer seulement la mousse liquide à prendre la forme du moule, sans pressage et/ou affaissement substantiel des cellules de la mousse et, ensuite, un refroidissement et une solidification de la mousse afin d'obtenir un article profilé.
- 35 2. Procédé selon la revendication 1, caractérisé en ce que la mousse liquide stabilisée (16) est une mousse fraîchement produite.
- 40 3. Procédé selon la revendication 1, caractérisée en ce que la mousse liquide stabilisée (16) est une mousse de métal stabilisée, coulée au préalable, qui a été chauffée à une température supérieure à la température solidus.
- 45 5. Procédé selon la revendication 1, caractérisé en ce que le moule (19, 25, 33) est réchauffé avant que la mousse liquide stabilisée (16) y soit pressée.
6. Procédé selon la revendication 1, caractérisé en ce que le métal est un alliage d'aluminium.
- 55 7. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la mousse liquide stabilisée (16) est pressée dans le moule (19) au moyen d'une plaque déplaçable (18).
8. Procédé selon la revendication 6, caractérisé en ce qu'une première plaque déplaçable (26) presse la mousse liquide stabilisée (16) dans le moule (25) et forme des surfaces extérieures lisses sur un article profilé en mousse

(27), et une deuxième plaque (29) est pressée dans la mousse liquide stabilisée se trouvant dans le moule (25), afin de former des surfaces intérieures lisses sur un article profilé en mousse (30).

- 5        8. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la mousse liquide stabilisée (31) est supportée sur une courroie en déplacement (32) et un moule inversé (33), se déplaçant verticalement en va-et-vient, est pressé vers le bas sur la mousse liquide stabilisée (16) se trouvant sur la courroie (32), afin de former de ce fait un article profilé en mousse (34).
- 10      9. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce qu'une pluralité de moules (40) montés sur une courroie transporteuse (42) prélèvent de la mousse liquide pressurisée (16) provenant d'un générateur de mousse, et la mousse prélevée par chaque moule est pressée dans le moule (40) au moyen d'une plaque (41) se déplaçant en va-et-vient.
- 15      10. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la mousse liquide stabilisée (16) comporte des cellules de taille uniforme.
- 20      11. Procédé selon la revendication 10, caractérisé en ce que les cellules de la mousse liquide stabilisée (16) présentent des tailles moyennes uniformes inférieures à 5 mm.
- 25      12. Procédé selon la revendication 1, caractérisé en ce que la coulée à la forme est une coulée à écrasement.
13. Procédé selon la revendication 1, caractérisé en ce que l'opération de coulée à la forme est suivie d'une opération de façonnage à la forme.
14. Procédé selon la revendication 5, caractérisé en ce que la mousse liquide stabilisée (16) est supportée sur un rouleau en déplacement (50) et un deuxième rouleau (53) est pressé dans la mousse liquide stabilisée (16) se trouvant sur le premier rouleau (50), afin de former de ce fait un article incurvé et profilé en mousse.

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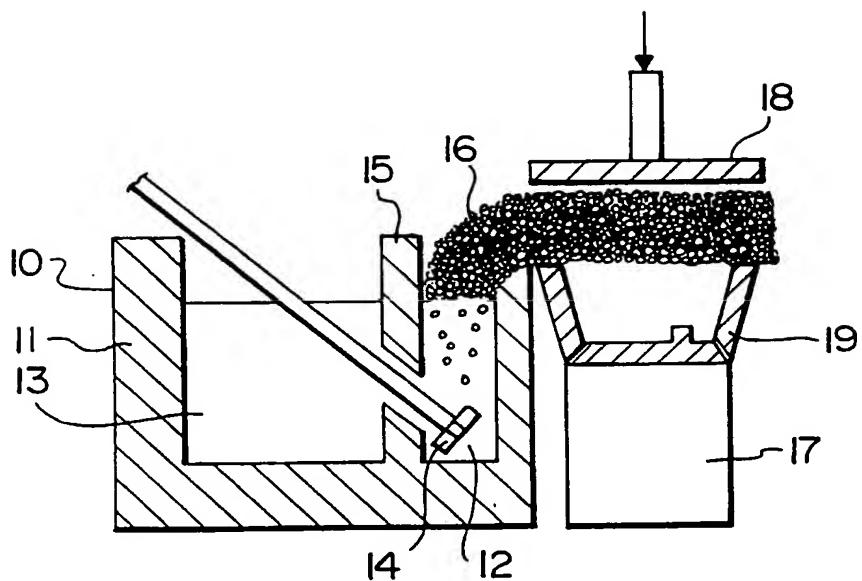


FIG. 1

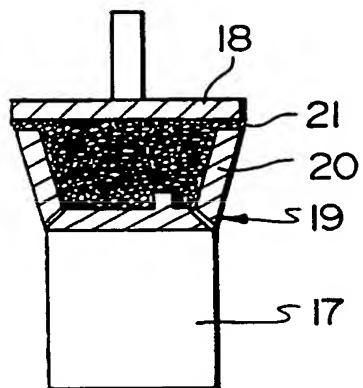


FIG. 2

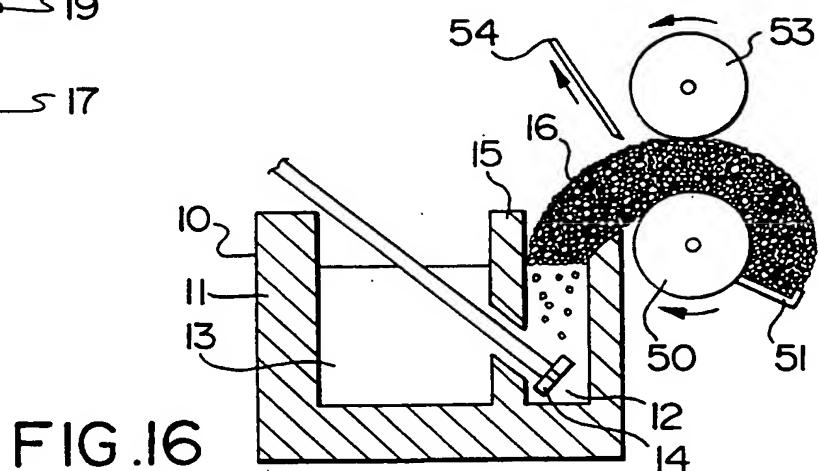


FIG. 16

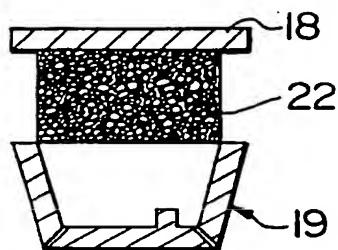


FIG. 3

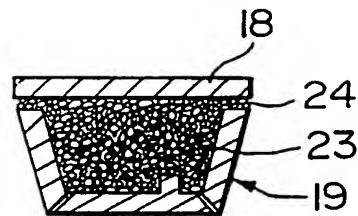


FIG. 4

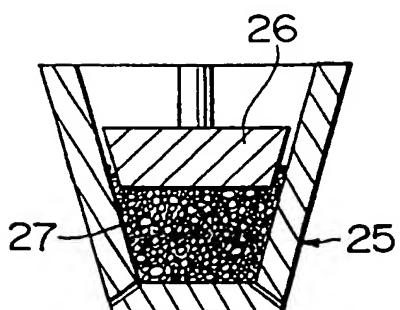


FIG. 5

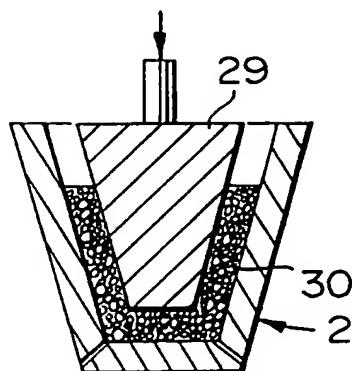


FIG. 6

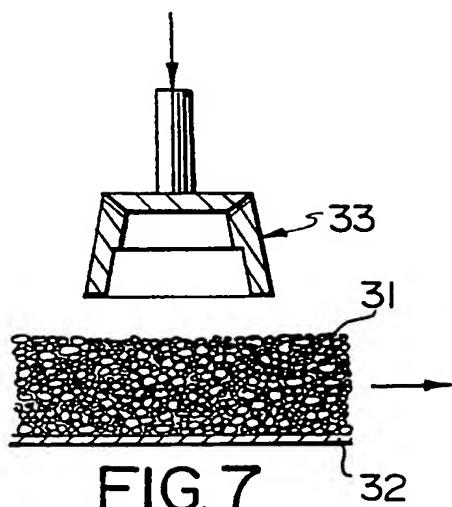


FIG. 7

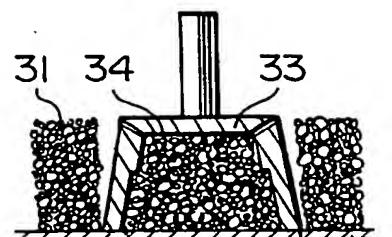


FIG. 8

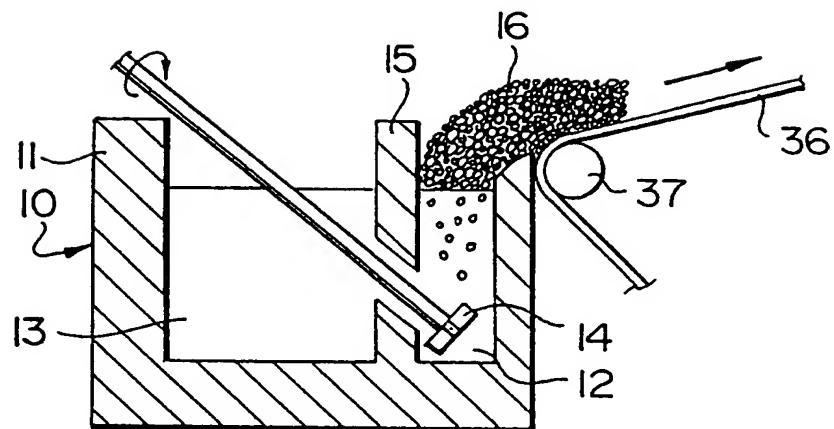


FIG. 9

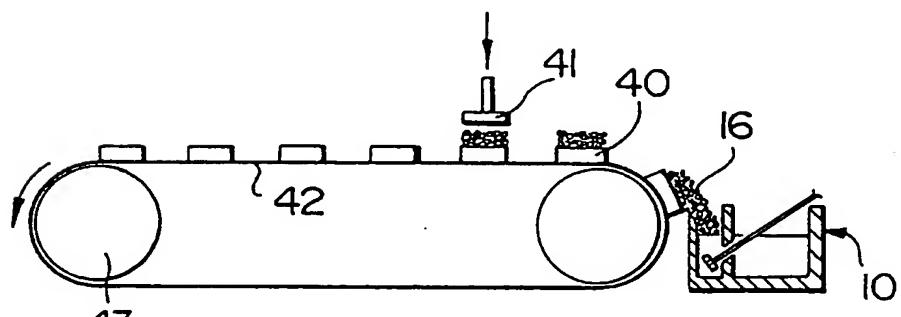


FIG. 10

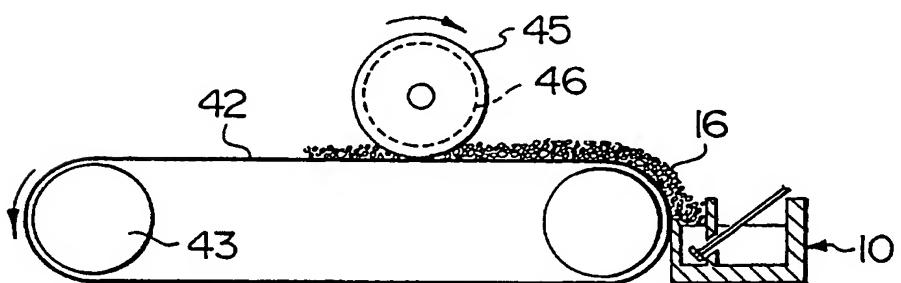
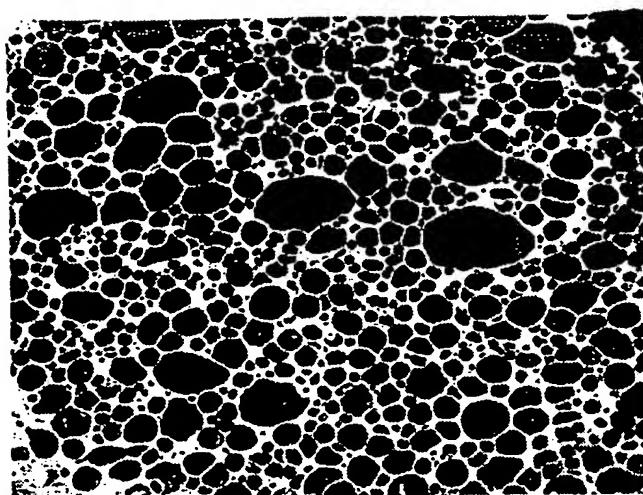


FIG. 11

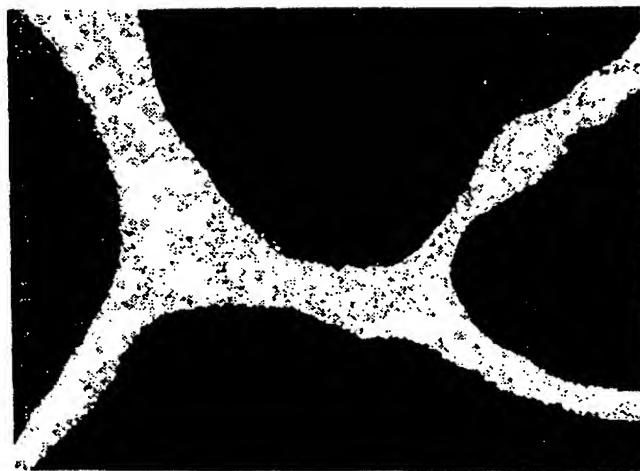
EP 0 666 784 B1



ML-21031

4X

FIG.12



ML-21032

100X

FIG.13



92-75

IX

FIG.14

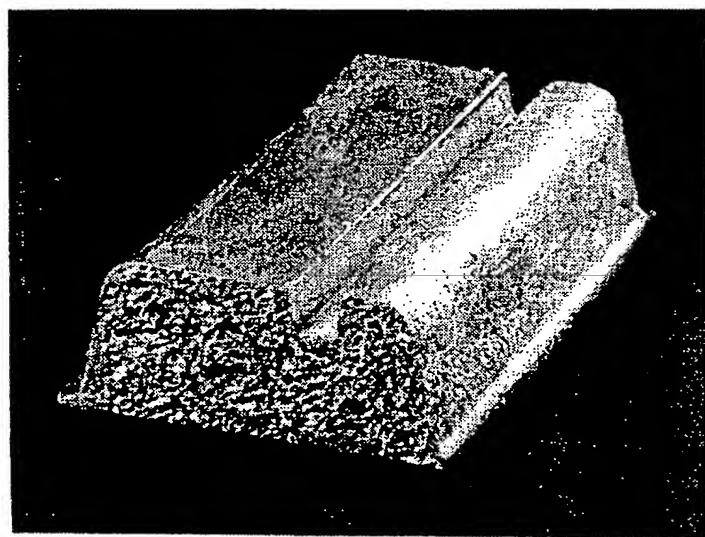


FIG.15

